

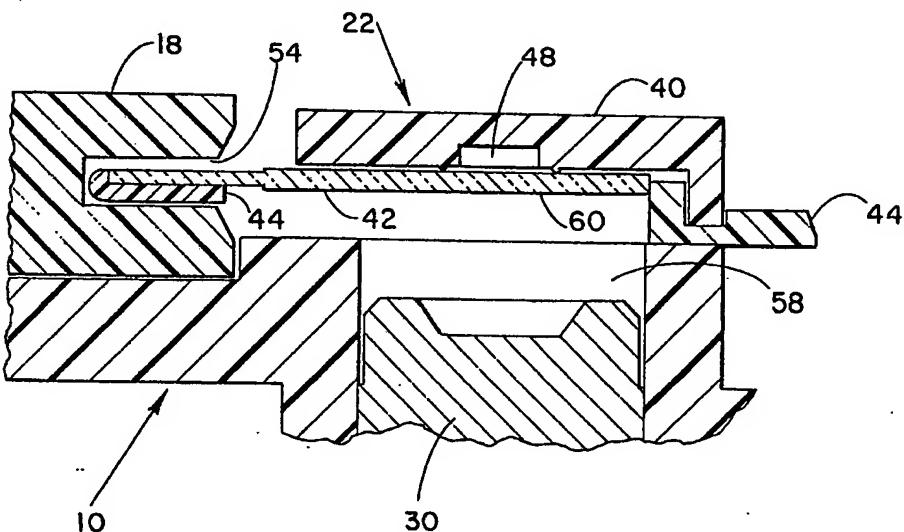


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(54) Title: TEMPERATURE CONTROL FOR PORTABLE DIAGNOSTIC SYSTEM



(57) Abstract

An accurate, low cost temperature control system for a portable diagnostic device or other electrochemical analytical device using a disposable cartridge (22) carrying an electrochemical sensing cell including a sample chamber (48) is disclosed. The disposable cartridge (22) may include its own heating element (52) on a sensor chip (42) and plugs into a terminal (18) which contains electrical input/output connections. The outer surface (60) of the chip (42) is exposed. A remote temperature sensor (30) which senses the temperature of the outer surface (60) of the chip (42) of the measuring cell (22) and generates a control signal which is used with conventional temperature control circuitry as the basis for thermostatic control of the cell temperature. The remote temperature sensor (30) is preferably a scanning infrared thermocouple probe.

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TEMPERATURE CONTROL FOR PORTABLE DIAGNOSTIC SYSTEM

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention is directed generally to 5 portable diagnostic systems based on electrochemical determinations in biological samples in which the control of sample temperature is important to analytical accuracy. More particularly, the invention concerns a system for controlling the temperature in a removable disposable 10 cartridge sampling unit for use with a portable diagnostic system. The system achieves rapid heating to and accurate control at a predetermined set point without the need for contact between any temperature measuring device and the disposable cartridge unit itself.

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II. Related Art

Methods and devices utilized for determining concentrations of electroactive species in solution using electrochemical or electrolytic methods such as, for example, the determination of pO_2 , pCO_2 and electrolytes in 20 blood samples, are well known. These instruments typically include a pair of electrochemical half cells, one of which is used as the sensor or sample half cell and the other as a reference electrode or a reference half cell. As is the case with any concentration determination of dissolved 25 gaseous species in a liquid, the temperature at which the electrochemical determination is made needs to be known. Traditionally, blood gas determinations, for example, have been made utilizing permanently installed laboratory instrumentation to which samples are brought for analysis. 30 Of course, in such instruments the temperature at which the sample is analyzed can be readily controlled as by a constant temperature oven, or the like. This, of course, is not practical in the case of a small portable device.

Thus, there remains a need for an inexpensive approach 35 to controlling the sample temperature in a portable blood gas analyzer or other such instrument that is easily manufactured and rapidly stabilizing and accurate.

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Accordingly, it is a primary object of the present invention to provide a temperature control system for use in conjunction with a portable analytical device which is simple, reacts rapidly and accurately controls sample 5 temperature.

It is a further object of the present invention to provide a non-contact temperature measurement system for a disposable test cartridge, so that prolonged or repeated use will not physically wear components to a state of 10 unreliability.

Yet another object of the present invention is to provide a temperature control system for a disposable cartridge electrochemical cell sampling device in which the disposable cartridge carries its own inexpensive internal 15 resistive heating element to heat the sample environment. A still further object of the invention is to provide a temperature control system for such a disposable cartridge which uses a temperature sensor that need not be directly connected to the disposable cartridge.

20 These and other objects will become apparent to those skilled in the art in accordance with the descriptions and drawings herein.

SUMMARY OF THE INVENTION

The present invention provides an accurate, low cost 25 temperature control system for a portable medical diagnostic device or other portable electrochemical analytical device which requires measurements to be made at a controlled temperature. In the preferred embodiment, a disposable cartridge carries an electrochemical sensing 30 cell including the sample chamber. The disposable cartridge includes its own resistive heating element on a sensor chip and plugs into a terminal connector which contains the necessary electrical input/output connections. The opposite or outer surface of the chip is at least 35 partially exposed to ambient air. A separate sensor probe is provided which senses the temperature of the outer surface of the chip of the measuring cell and uses that

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sensed temperature to generate a signal which is used in conjunction with conventional temperature control circuitry which is designed with a control set point and which thermostatically controls the resistive heater element to 5 rapidly reach and accurately control the desired cell temperature when the disposable cartridge is inserted into the portable diagnostic device. The temperature sensing probe is preferably one of a type of scanning infrared thermocouple probes which combine speed and accuracy with 10 a readily usable output signal.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, wherein like numerals are utilized to designate like parts throughout the same:

15 FIGURE 1A is a fragmentary perspective instrument sub-assembly view depicting the sample measurement cartridge temperature control system of the invention;

FIGURE 1B is an exploded view of the perspective instrument sub-assembly of Figure 1A;

20 FIGURE 2 is an enlarged, fragmentary sectional view of a portion of the system of Figures 1A and 1B;

FIGURE 3 is a sectional view taken substantially along line 3--3 of Figure 4;

FIGURE 4 is a top view of the system of Figures 1A and 1B; and

25 FIGURE 5 is a computer generated plot depicting the temperature control of the sample solution in the electrochemical cell of a cartridge in accordance with the invention including reaction to induced traumatic temperature stimuli.

30 DETAILED DESCRIPTION

The instrument sub-assembly depicted in the several views of the drawings is part of a larger portable instrument which makes analytical determinations such as blood gas analysis. The instrument uses a disposable 35 cartridge which contains a calibrated electrochemical cell designed to receive and electrochemically measure a sample injected into a sample port associated with the cartridge.

The integral electrochemical cell of the cartridge is carried on a sensor chip and includes a resistive heating element also preferably formed on the sensor chip member. Electric input to the heating element is thermostatically controlled by a non-contact temperature sensitive device, such as a scanning infrared probe, which monitors the temperature of the outer surface of the sensor chip and controls input to the resistive heating element through conventional temperature control circuitry. Of course, the particular embodiment shown is merely illustrative of the several unique features and principles which may be more broadly applied by those skilled in the art.

Accordingly, Figures 1A and 1B depict, in perspective, and partially schematically, an instrument sub-assembly integral with a larger device and including a removable cartridge and cartridge receiving retaining device together with a temperature control system for the removable cartridge. The system includes an instrument sub-assembly housing shown generally at 10 which may be fastened to the main body of a larger portable instrument (not shown) as by utilizing openings or holes 12 in the housing. As can best be seen by Figure 1B, the housing 10 further contains a recess 14 and a connecting block 16 for receiving and retaining, as by screws (not shown), an electrical connector or terminal block 18. The connector 18 includes a plurality of electrical input/output terminals 20 which physically retain and electrically connect a removable cartridge system, depicted generally at 22, with the main portion of the analytical instrument (not shown) as required.

The connector element 18 is shown schematically connected to conventional temperature control circuitry which operates in a well-known manner and is designated by the box 24 using a pair of conductors 26 and 28. The temperature sensing input for the temperature control system is provided by a non-contact temperature sensor which is preferably in the form of an infrared scanning

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thermocouple device or probe 30 which senses temperature rapidly and accurately. The probe 30 is connected to the temperature control circuitry as by conduit 32. The signal received from the probe is processed by the temperature 5 control circuitry and compared with a value corresponding to a fixed designed set point control temperature determined by the application involved, typically about 37°C or body temperature.

The housing 10 contains a pair of integral retainers 10 34 which are configured to fit over and slidably receive the removable sample cartridge system 22. The sample cartridge, of course, is depicted in the exploded view of Figure 1B, and includes a top member 40, sensor chip 42 and a base member 44. The top member 40 further includes port 15 46 which is used to admit a temperature probe for experimental verification purposes. A sample receiving port is located at 47. As illustrated in Figures 2-4, the top member 40 contains a recess which, with the sensor chip member 42, forms a volume 48 for containing the sample. 20 The chip 42 further contains a plurality of electrodes illustrated by 50 and carries a serpentine resistance heating element 52 which is electrically connected to the conductors 26 and 28 utilizing the connector 18 when the cartridge 22 is plugged into the recess 54. The lower 25 member or base member 44 is recessed to receive the chip 42 and further contains a central opening 56 which provides an external window to expose the outer surface 60 of the chip 42. The opening 56 aligns with an opening 58 provided through the housing member 10 giving the probe 30 a direct 30 line of sight of the outer surface 60 of the chip member 42 for the purpose of temperature detection.

The probe 30 may be any suitable scanning infrared sensor, or the like. Examples include one known as IR t/c® available from Exergen Corporation of Newton, 35 Massachusetts. Such probes can be produced and pre-calibrated in quantity prior to manufacture of the portable measuring instruments so that they will repeatably, rapidly

and accurately control the temperature of the observed surface, for example, at $37^{\circ}\text{C} \pm 0.2^{\circ}\text{C}$. The signal produced by the temperature sensed by the probe 30 is transmitted by a conduit 32 to the control circuitry 24 which, in turn, 5 controls the electric power in conductors 26 and 28 to modulate the energy output of the serpentine resistance element 52 in a well-known manner.

In operation, a fresh disposable cartridge is inserted into the portable instrument so that proper electrical 10 connection is made in opening 54 and the cartridge is also retained in place by ears 34. In connection with this operation, the temperature control system can be automatically activated by the insertion of the cartridge into the receptacle 54. The system may contain any desired 15 time delay circuits or other activation system. Of course, the device may also be controlled by other means such as an instrument switch (not shown) in a well-known manner.

Figure 5 depicts a computer generated graphical plot illustrating the ability of the temperature control system 20 of the invention to control the solution temperature of the electrochemical cell volume 48 of a disposable cartridge made in accordance with the preferred embodiment. The probe and temperature control circuitry are designed to control the temperature of the solution in the 25 electrochemical cell at about 37.5°C when stabilized. The time-temperature plot of Figure 5 illustrates the reaction of the system after activation at approximately 10 seconds into the time plot along the abscissa. The temperature data for the plot of Figure 5 was obtained by means of a 30 temperature probe inserted into the cell through port 46. Actual temperature values sensed by the probe may be mathematically compensated in the control circuitry to represent actual sample solution temperatures in the cell. The time-temperature profile using the inserted temperature 35 probe in any event is quite similar and representative of the control capabilities of the system. As can be seen from Figure 5, the temperature was raised from an ambient

temperature of approximately 24°C to the control temperature of approximately 37.5°C at the 32-second mark. At approximately the 71-second mark, the system was shocked by the injection of approximately 5 cc of ice water as through 5 the port 47. Within about 1-2 seconds, the temperature dropped to approximately 11°C, the low point of the cycle. Thereafter, the recovery was again extremely rapid and reached the control point of approximately 37.5°C in about 10 35 seconds. Figure 5 aptly illustrates the rapidity with which the system recovers to the desired control temperature and the accuracy with which that temperature can be maintained in accordance with the invention.

The chip member 42 is normally fabricated of a thin ceramic with a fairly low thermal capacity for easy 15 temperature control and quick recovery. The serpentine resistive heating element together with connecting conductors is normally deposited on the surface of the chip using screen printing thick film or one of many well-known metallizing techniques. Such resistive heaters may be made 20 of any conventional material such as permalloy (an alloy having a preferred composition of 80% nickel and 20% iron). The material may be deposited as a thick or thin film in any desired configuration. The chip 42 itself may be any 25 ceramic or other convenient dielectric material which meets the criteria for both the electrochemical cell and lends itself to temperature control utilizing the heating system of the invention.

This invention has been described herein in considerable detail in order to comply with the Patent 30 Statutes and to provide those skilled in the art with the information needed to apply the novel principles and to construct and use embodiments of the example as required. However, it is to be understood that the invention can be carried out by specifically different devices and that 35 various modifications can be accomplished without departing from the scope of the invention itself.

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For example, the resistive heating element 52 can be replaced by a different heating means such as a remote millimeter wave generating device or other radiant heating device. Of course, the invention also contemplates use 5 with devices which require temperature control but which do not require an electrochemical cell.

CLAIMS

We claim:

1. A temperature control system for controlling the temperature in a disposable cartridge sampling unit for a portable diagnostic system comprising:
 - a disposable cartridge further comprising;
 - means for containing a sample volume,
 - a sensor substrate having oppositely disposed inner and outer surfaces, the inner surface being in contact with the sample volume and carrying one or more electrochemical cell means for making one or more measurements with respect to a sample placed therein, the sensor substrate further carrying integral electrical heater means,
 - electrical conductor means for conducting electrical energy to the heater means;
 - mounting means for removably receiving and electrically connecting the disposable cartridge to a larger, portable diagnostic device;
 - temperature sensing means for sensing the temperature of a surface of the sensor substrate without direct contact with the cartridge or direct exposure to the heating element itself and generating an electrical signal related to the sensed temperature;
 - control means for controlling the electrical input to the heater means based on the sensed temperature and a designed control temperature.
2. The apparatus of claim 1 wherein the temperature sensing means is an infrared probe.
3. The apparatus of claim 1 wherein the electrical heater means is a resistance heater integral with one surface of the sensor substrate.
- 35 4. The apparatus of claim 3 wherein the electrical heater means is a thick film resistor and the sensor substrate is a dielectric chip.

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5. The apparatus of claim 1 wherein the surface of which the temperature is sensed is the sensor substrate surface opposite that carrying the electrochemical cell means.

5 6. The apparatus of claim 4 wherein the surface of which the temperature is sensed is the sensor substrate surface opposite that carrying the thick film resistor.

7. The apparatus of claim 4 wherein the temperature sensing means is an infrared probe.

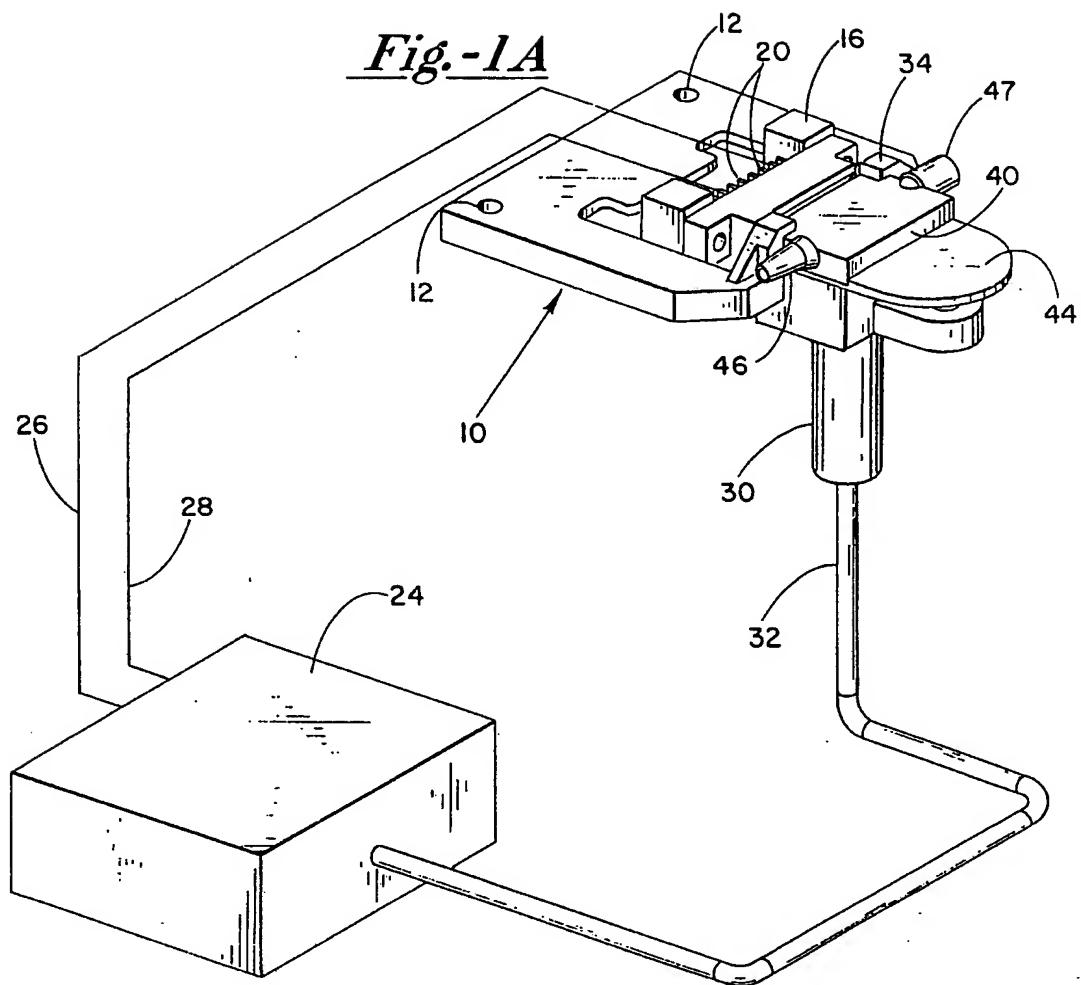
10 8. The apparatus of claim 5 wherein the temperature sensing means is an infrared probe.

9. The apparatus of claim 6 wherein the temperature sensing means is an infrared probe.

10 15. The apparatus of claim 1 wherein the temperature control system includes means activating the temperature control system which is activated by connecting the disposable cartridge in the mounting means.

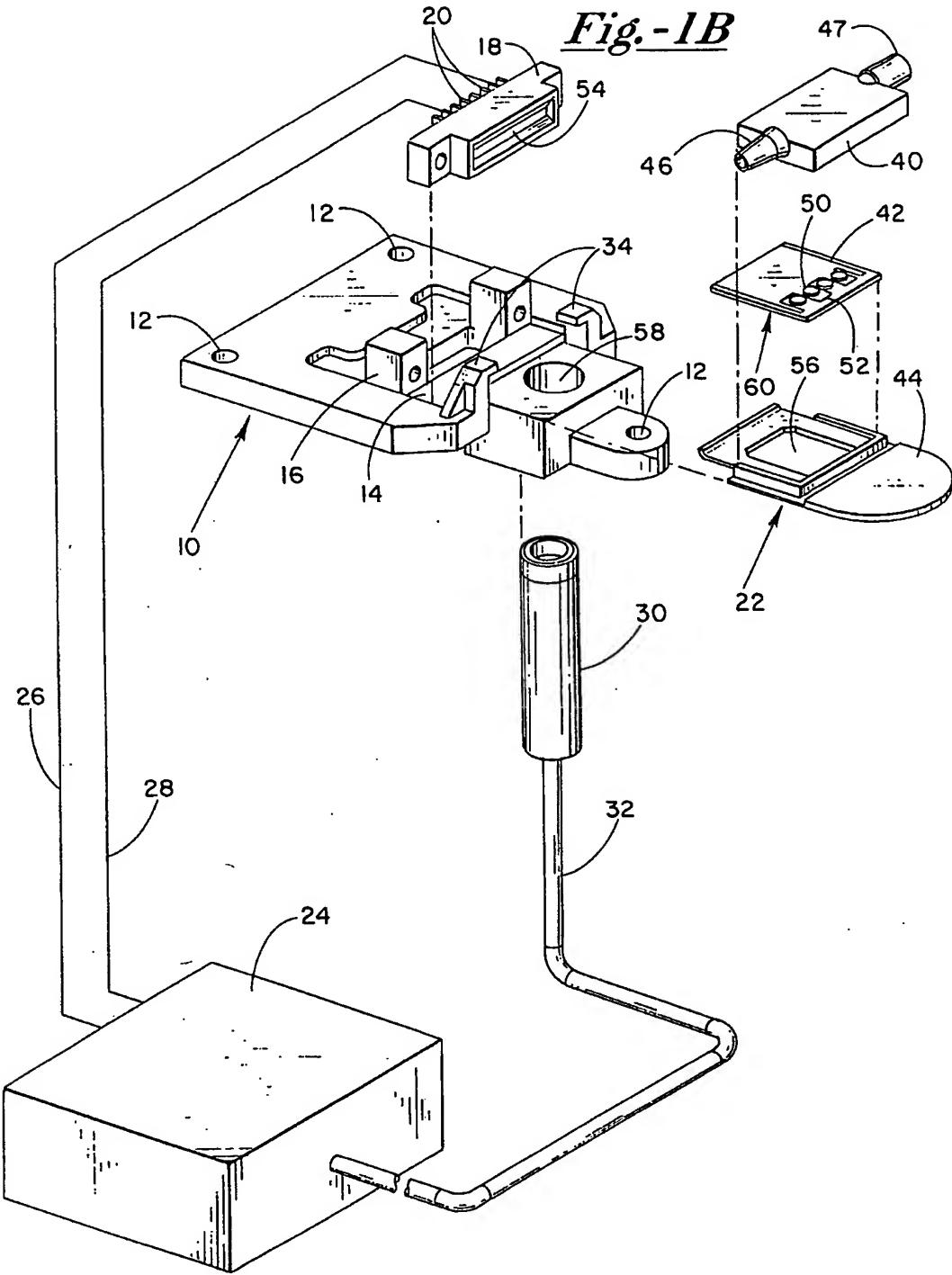
11. The apparatus of claim 6 wherein the temperature control system includes means activating the temperature control system which is activated by connecting the disposable cartridge in the mounting means.

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Fig. - 1B



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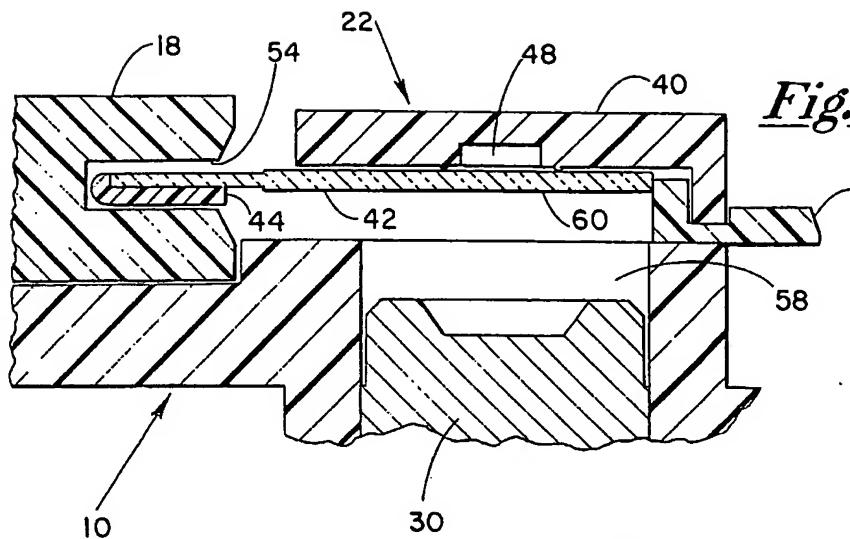


Fig.-2

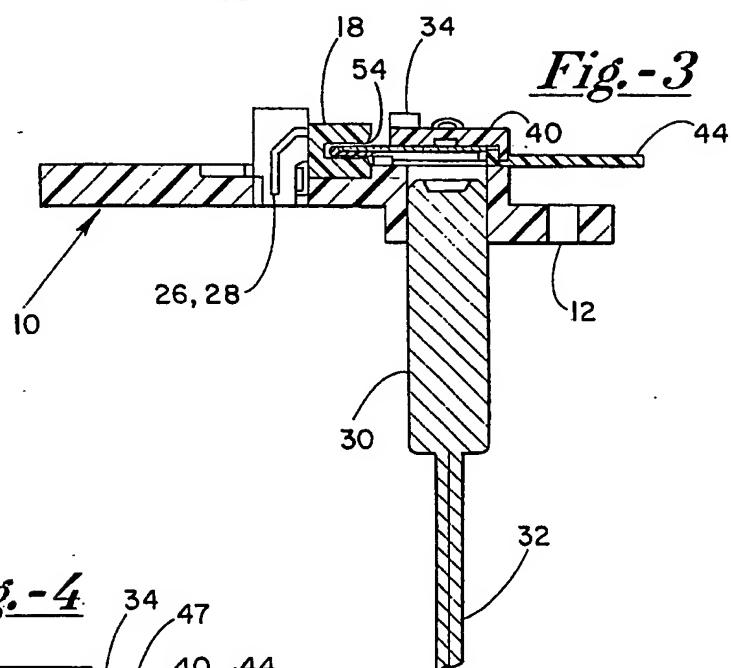


Fig.-3

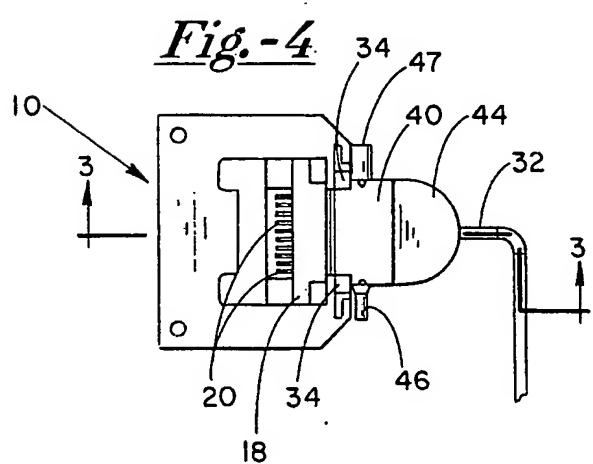
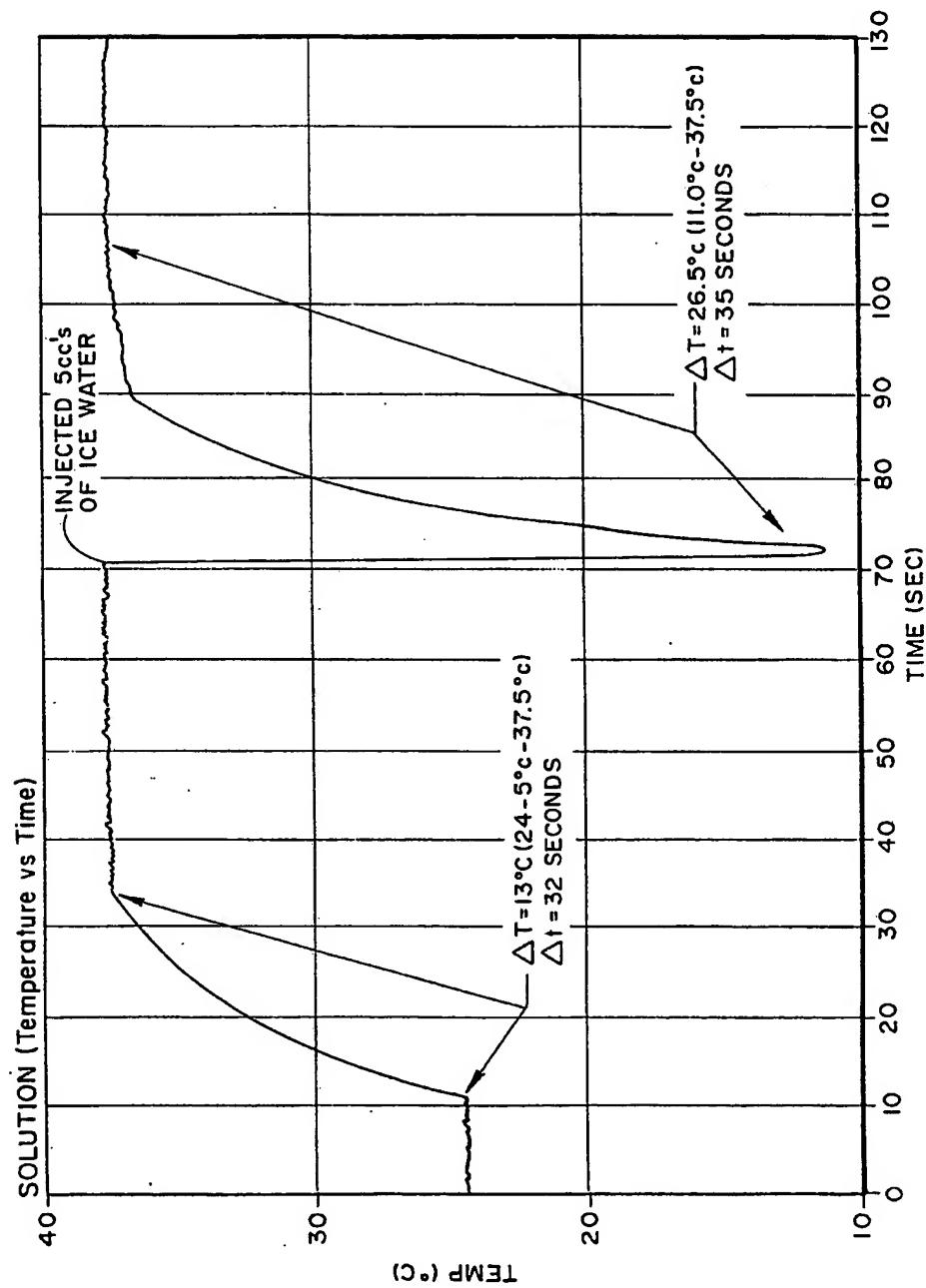


Fig. - 4

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Fig. -5

INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US93/04559

A. CLASSIFICATION OF SUBJECT MATTER

IPC(S) :G01N 27/28; G05D 23/27

US CL :Please See Extra Sheet.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 204/153.1 408, 412, 416; 374/121, 141; 422/68.1, 82.01, 82.02, 82.03, 82.04, 99, 105, 109

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

ASP search terms: exogen, infrared, ir, infra red, scanning, temperature

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 4,225,410 (Pace) 30 September 1980.	1-11
A	US, A, 4,271,119 (Columbus) 02 June 1981.	1-11
A	US, A, 4,361,540 (Weinberg et al) 30 November 1982.	1-11
A	US, A, 4,397,725 (Enzer et al) 09 August 1983.	1-11
A	US, A, 4,453,151 (Leary et al) 05 June 1984.	1-11
A	US, A, 4,654,127 (Baker et al) 31 March 1987.	1-11

 Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:		
A document defining the general state of the art which is not considered to be part of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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Date of the actual completion of the international search	Date of mailing of the international search report
14 July 1993	02 AUG 1993
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/04559

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 4,654,624 (Hagan et al) 31 March 1987.	1-11
A	US, A, 4,762,594 (Guruswamy) 09 August 1988.	1-11
A	US, A, 4,786,394 (Enzer et al) 22 November 1988.	1-11
A	US, A, 4,831,258 (Pault et al) 16 May 1989.	1-11
A	US, A, 4,929,426 (Bodai et al) 29 May 1990.	1-11
A	US, A, 4,988,211 (Barnes et al) 29 January 1991.	1-11
A	WO, A, 88/00708 (Conover et al.) 28 January 1988.	1-11

INTERNATIONAL SEARCH REPORT

International application No.

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A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

204/408, 412, 416; 374/121, 141; 422/68.1, 82.01, 82.02, 82.03, 82.04, 99, 105, 109